REMARKS

Reconsideration and allowance of the subject application are respectfully requested.

A. Summary of the Office Action and Outline of Response

Agreement was reached during the personal interview conducted on April 14, 2004 that all outstanding rejections and objections be withdrawn as reflected in the interview summary. Nevertheless, after reconsidering the matter, the Examiner has reinstated the same rejections.

Below Applicants provide a summary response to the official action. The response further includes a detailed, point-by-point response and rebuttal drafted by the inventors to each of the points raised by the Examiner. It also explains why the Examiner's criticism of the expert testimony of Dr. Dwight Rickel is unwarranted. This detailed, point-by-point response and rebuttal is attached as Appendix A and includes a list of references and several figures. Copies of those cited references that have not already been supplied to the Examiner are included in Appendix B and listed on a PTO-1449 form supplied with an Information Disclosure Statement.

B. The Claimed Invention Is Useful and Enabled

To sustain a lacking of finding utility, there must be proof of total incapacity. *Juicy Whip Inc. v. Orange Bang Inc.,* 51 USPQ 2d 1700, 1702 (Fed. Cir. 1999). Evidence submitted by the Applicant to rebut the finding need only (1) "explicitly identify a specific and substantially utility for the claimed invention," and (2) "provide

evidence that one of ordinary skill in the art would have recognized that the identified specific and substantially utility was well-established at the time filing." MPEP §2017, at pages 2100-2130. Applicants need only come forward with evidence that the invention is capable of performing some beneficial function or achieving some useful result. *Juicy Whip Inc. v. Orange Bang Inc.* at 1702. There is no requirement that Applicants prove an asserted utility beyond a reasonable doubt, *In re Irons,* 144 USPQ 351, 354 (CCPA 1965), or that an asserted utility is established as a matter of statistical certainty. *Nelson v. Bowler,* 206 USPQ 881, 883-884 (CCPA 1980).

The Office Action objects to certain words as not being conformity with the "general terminology accepted in the art." Applicants respectfully disagree. The Examiner further rejects the claims under 35 U.S.C. §101 contending that the claimed invention lacks utility. The Examiner's rejection is in error.

Evidence previously submitted by Applicants directly rebuts the Examiner's incredibility contentions and demonstrates the utility of the claimed invention. That evidence includes two Bolotovski articles cited and discussed in the specification at page 3, lines 10-20, (copies of these articles are included in the Information Disclosure Statement submitted with this response), the expert testimony of Dr. Dwight Rickel submitted in a Rule 132 Declaration, and a description of an experiment performed by the inventors using the invention along with specific experiment results (submitted as exhibits C and D with Dr. Rickel's Declaration).

Before the filing of this application, the Bolotovski articles established in the technical literature that coordinated motion of aggregates of charged particles can give rise to extended electric charges and currents whose distribution patterns propagate with a phase speed exceeding the speed of light in a vacuum, and that once created, such propagating charge distribution patterns act as sources of electromagnetic fields in precisely the same way as any other moving sources of these fields. As the specification explains on page 3, the fact that these sources:

> travel faster than light is not, of course, in any way incompatible with the requirements of special relativity. The superluminally moving [charge or current distribution pattern] is created by the coordinated motion of aggregates of subluminally moving particles.

Dr. Dwight Rickel is an expert in the technical field of this invention. See Rickel Declaration, ¶'s 1-3. Dr. Rickel confirms that the claimed invention does not violate known laws of nature, including the special theory of relativity. Rickel Declaration, ¶7. There is no *material object* accelerated to a superluminal speed in a vacuum. Again, it is the *moving distribution pattern of the current* which reaches superluminal speed. Rickel Declaration, ¶'s 5 and 7.

Dr. Rickel also confirms that the invention generates a cusp of intense radiation that is not produced by conventional radiation sources. Rickel Declaration, ¶ 8. Dr. Rickel states in ¶ 8:

> Moving away from the distribution, more wavelets converge on the cusp giving rise to non-spherical decay in the far field better than $1/R^2$.

The experiments conducted by the inventors to test the viability of the invention and described in exhibit C of the Rickel declaration was validated by Dr. Rickel. Rickel Declaration, ¶ 10. Figure 3 of the test results in exhibit D confirms, as explained in the Rickel Declaration, ¶ 11, that:

> [t]he radiation intensity in Figure 1 decays at a rate of approximately $1/R^2$ once account is taken of interference from the ground, while the slope of a line corresponding to that ratio confirms that the intensity in Figure 2 decays at a rate of approximately $1/R$, where R is the distance from the charge or current distribution.

Non-spherically decaying electromagnetic radiation clearly has a plethora of beneficial uses. Various example and non-limiting uses are set forth in the claims, described in the application, and identified by Dr. Rickel. Rickel Declaration, ¶6.

In the second action, the Examiner maintains his contention that the claims and specification terminology are incompatible with the requirements of the special theory of relativity. This is not so because:

(a)   There is no superluminal motion of anything that is material (i.e., has non-zero rest mass) in the invention. The superluminally moving distribution pattern of the polarization current that is generated by the claimed apparatus arises from the coordinated motion of aggregates of subluminally moving charged particles; it is not the type of object that is barred from moving faster than light by special relativity.

(b)   A *source* of electromagnetic radiation need not be material or have rest mass. Superluminally moving distribution patterns of macroscopic charges and currents

act as sources of the electromagnetic field in precisely the same way as any other moving sources of these fields.

(c)   The motion that is associated with the distribution pattern of a macroscopic charge or current is not in any way restricted; it can be with or without acceleration.

(d)   Terms such as "superluminal velocity" and "superluminal source" are common terminology in the literature on the subject which have appeared in the titles of numerous published papers.

(e)   The Examiner's contention disagrees with the assessments of the referees and editors of the prestigious journals *(Journal of the Optical Society of America A, Journal of Applied Physics* and *Physical Review E)* which have published the inventors' theoretical calculations and experimental data supporting this invention. If the Examiner's objection was well founded, such established journals would certainly have published results to demonstrate that special relativity is violated. But such journals did not. Thus, the opinion of the Examiner is more than amply rebutted by the published assessments of the referees and editors of the prestigious journals noted above.

The Examiner further contends that the opinions expressed in certain popular-science articles constitute "a general criticism launched by the scientific community, which provides a basis for the §101 rejections raised" in the Office Action. These articles, which predate the publication of Applicants' experimental results, only report unsupported opinions about the chances of success of Applicants' experiments. Given

that both the theoretical and experimental accounts of Applicants' invention have been recommended for publication by those experts in the field (including the referees of highly prestigious specialist journals) who have studied them, the question as to how to gauge the *considered* opinion of the scientific community about this invention is not a controversial one. Moreover, the critiques of the Applicants' theoretical work that have appeared in academic journals were printed prior to the publication of their experimental results. Those critiques have been replied to in print.

The Examiner further contends that a non-spherically-decaying radiation is incompatible with the requirements of the conservation of energy. This is not so because the beam that may be generated using Applicants' invention is non-diffracting in the direction parallel to the rotation axis. Its polar beam width decreases like $1/r$ with increasing r, so that its cross-sectional area increases as r rather than as r^2 (see Fig. II in Appendix A). Thus, the flux of energy across any given surface enclosing the source is independent of r (as required by the conservation of energy).

The Examiner also contends that a longer range (10—80 km) is needed to test the $1/r$ decay of the non-spherically-spreading component of the radiation. This is not so because there is no parameter other than the Fresnel distance to limit the range of validity of the predicted results. These results have been experimentally tested to several hundred Fresnel distances.

C. The Examiner's Criticisms of the Experimental Data Are Not Justified

The Examiner contends that there are discrepancies between the content of the specification and the experimental results. For the Examiner's information, those experimental results have also been published by the "published by the Journal of Applied Physics" (see Ref. 8 included in Appendix B). Indeed, the publication of the inventors' articles The Examiner's contention is erroneous because:

(a)   The spiraling cusp that is shown in Fig. 4 of the specification is generated by a rotating *point* source. The cusps that are generated experimentally, i.e., by an extended continuous source distribution, are stationary and straight as shown in Fig. II in the detailed response attached as Appendix A. The direction along which Applicants' measurements are made is not perpendicular to the axis of rotation, as alleged by the Examiner. Rather, the apparatus was tilted so that this direction falls outside the plane of rotation along the cusp.

(b)   The fact that the ratio plotted in Figs. 11(a)—(d) of Exhibit D of the Rickel declaration (and Ref 8—a copy is in Appendix B) has a value that is smaller than 1 at $r = 150$ m does not mean that the new emission mechanism is less efficient than a conventional one, as alleged by the Examiner. To the contrary, it means that the particular example and non-limiting embodiment of the invention used in the reported experiments generates a weaker polarization current when run superluminally than when run subluminally.

(c)   The spherically-decaying component of the radiation generated by Applicants' experimental apparatus has a continuous spectrum containing a wide range of frequencies; it does not consist of just the sum and difference of the two frequencies used for synthesizing the source, as alleged by the Examiner. As explicitly stated in Exhibits A and D of the Rickel declaration and in Ref. 8 included in Appendix B, the experimental data published by the inventors are concerned only with the *amplitude* of the spherically-decaying radiation at these two dominant frequencies.

(d)   The inventors' experimental geometry does not coincide with the geometry of a linear phased array, as alleged by the Examiner. A cusp would not have been generated had there been no curvature in the trajectory (and so no acceleration in the motion) of the distribution pattern of the source. The Examiner's misconception that "if there is any acceleration in the experiment, it is the acceleration of an oscillating dipole" stems from his having overlooked the distinction between the motion of charged particles that give rise to the polarization current and the motion of the distribution pattern of this current.

(e)   The "Cerenkov-like cone of radiation" consists, in the present case, of the two-sheeted surface shown in Fig. 3 of the instant application and *not* of the two cones that the Examiner has drawn on Fig. 3 of the Office Action. A distinguishing feature of invention is that it replaces the Cerenkov cone by a surface that is cusped.

D. The Claim Terms Are Definite

The claim terms are definite when read in light of the specification by a person skilled in the art. The term "accelerating" is a very well known accepted term in the art. It simply means a change in velocity with respect to time. The direction of acceleration has not been specified in the claims because the claims hold true for an acceleration in any direction. The two particular cases where the acceleration is linear or centripetal have been discussed in the specification.

In addition, the Examiner's understanding articulated at the top of page 29 of the office action is not correct. In the present application, the radiation is focused along a curve in space and not at a single point, as discussed in the references quoted by the Examiner. Secondly, the direction of acceleration of the source synthesized by the inventors for obtaining the reported experimental data is perpendicular to the array direction and not parallel to it as thought by the Examiner.

The terms "long" and "significant" in claim 68 have been removed, and the new language is believed definite and distinct.

E. The Applied Prior Art Is Not Applicable

The Examiner makes an anticipation rejection based on USP 6,611,230 to Phelan and a number of obviousness rejections starting with the combination of Geyh and Phelan and adding further references from there. As an important first matter, none of the prior art rejections is appropriate because *the primary Phelan reference upon which all the rejections rely is not prior art to the instant claims*. Phelan's US filing date is

December 11, 2000. The international filing date of the instant application of September 6, 1999 precedes Phelan's U.S. filing date by more than a year. Moreover, the foreign priority date of the instant application is more than two years before Phelan's U.S. filing date. Thus, all prior art rejections are improper and should be withdrawn.

But even if these rejections could be made, they are all based on a faulty claim construction that ignores the meaning of claim terms that one of ordinary skill in the art would attribute to them in light of the teachings of the instant specification and the experimental results for the example embodiment of the invention. Ultimately, the rejections simply do not teach what is claimed.

The Examiner contends that the claims cannot be distinguished from a conventional phased-array antenna and that the phase shifts that give rise to the superluminal speed of the claimed source are no different from those which are used for operating such antennae in a beam forming/steering mode. This is not correct for the following reasons:

(a)   Consisting of a *discrete* set of radiating elements, a conventional phased-array antenna generates a field in the radiation zone which is the same as that of a collection of distinct *point-like* sources. In contrast, the field that is generated by the claimed apparatus in the radiation zone is the same as that of an extended, *continuous* source distribution (see Fig. I in Appendix A). For the radiation to have the novel attributes described in the instant application, the source should be volume-distributed and continuous, rather than discrete.

(b)   There is a sharp distinction between the superluminal phase velocity that the Examiner associates with the *discrete* set of elements in a phased array and the superluminal phase velocity of the *continuous* traveling wave that constitutes the distribution pattern of the polarization current in the claimed apparatus. Unless there exists a dense collection of moving source elements (volume elements of the rotating distribution pattern of an extended and continuous electric current) that approach the observer with the speed of light and zero acceleration along the radiation direction, no cusps would be formed at the position of the observer at the observation time. The cusp makes the radiation emitted by the *continuous* current distribution generated in the claimed apparatus fundamentally different from that which is emitted by a discrete collection of elements.

(c)   The intensity of the radiation from a conventional source (including a phased array antenna) decays like $1/r^2$. In contrast, the intensity of the radiation from the claimed apparatus decays like *1/r*. This difference has been established both theoretically and experimentally.

(d)   None of the references applied by the Examiner describes or is concerned with continuous source distributions.

(e)   The experimental apparatus (whose length is of the order of only a wavelength of the radiation it emits) has been observed to generate a focused beam of polar width ~ 2° with an intensity that decays like *1/r*, rather than $1/r^2$, over the

experimentally available range (which amounts to several hundred Rayleigh ranges). No radiation with such characteristics has ever been reported in the published literature and certainly is not described in the applied references.

The Examiner further contends that the non-spherically decaying component of the radiation (the component whose intensity diminishes like $1/r$ instead of $1/r^2$) is generated also by lasers and directional phased-array antennae. This is not so because the non-spherical decay of a laser or any other directional beam cannot persist to infinity. Whether a collimated laser beam starts spreading at one or at "many multiples" of the Rayleigh distance from its source makes no difference to the fact that the intensity of a laser beam (unlike that of non-spherically decaying radiation) decays like $1/r^2$ as $r \to \infty$. In addition, no *constructive* interference (such as that responsible for the diffraction-free regime of a collimated laser beam) can persist far beyond the Rayleigh distance. In contrast, the $1/r$ decay rate of radiation achieved by the technology described in the instant application holding as far as $r \to \infty$ has been tested to several hundred Rayleigh distances. There is no comparable achievement or comparable data in the published literature on laser or any other beams.
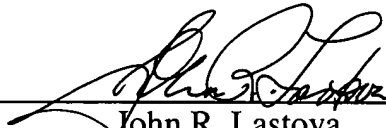
The Examiner and SPE Lee are requested to reconsider and withdraw the outstanding rejections in light of the information provided above, in the detailed response of Appendix A, and in the materials provided in Appendix B. The application is in condition for allowance. An early notice to that effect is earnestly solicited.

ARDAVAN et al.
Appl. No. 09/786,507

Respectfully submitted,

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Response to the objections of the Examiner: US Patent Application No. 09/786,507, Arzhang Ardavan, et al.

In what follows we respond to the points made by the Examiner in the order in which they appear in his report; the numbering of the Paragraphs below directly corresponds to that which appears in the Office Action.

1–3. No comment required.

4. It is not true that "there is no 'superluminal velocity' whatsoever"; it is only a material object with a rest mass that cannot move with a superluminal velocity. The distribution patterns of macroscopic charges and currents have no rest mass and so *can* travel with a superluminal velocity. Superluminally moving distribution patterns of charges and currents act as sources of the electromagnetic field in precisely the same way as any other moving sources of these fields (see, e.g., Refs. 1–9). A *source* of electromagnetic radiation need not be material or have a rest mass. Anything that gives rise to electromagnetic waves can be referred to as a source of the electromagnetic radiation; the relevant meanings given in the Webster's Dictionary for the word "source" are "that from which something comes or develops" and "prime cause".

Nor is a superluminal velocity always caused by a "phase delay". Superluminally moving continuous sources of the electromagnetic field have been created in the laboratory also by shininig a moving pulse of X-rays onto a medium that can be ionized (Ref. 5), i.e., by methods involving no phase shift. The experimental results that are reported by Bessarab et al. in Ref. 5 verify the existence of the Čerenkov effect in vacuum; they represent an independent confirmation of the fact not only that a source of the electromagnetic field need not be material, but also that the massless sources of the electromagnetic field can move faster than light *in vacuo*.

The publication in a wide range of established scientific journals of the sample of papers referred to here (Refs. 1–9), each of which uses either the phrases "superluminal source" or "superluminal velocity" in its title, clearly indicates that the Examiner's objection to our terminology is unfounded.

5. Claim 32 has been amended to correct the dependency.

6. No comment required.

7.(a) As explained in Paragraph 4, the superluminally rotating sources discussed in the disclosure are not material objects (i.e. have no rest mass) and so do not contravene the principle of causality or any other requirements

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of the special theory of relativity. The statement appearing in the news item on the website <http://physicsweb.org/article/news/8/7/161> that is quoted by the Examiner has been made by A. Hewish without qualification. The exchange of published comments between A. Hewish and one of us (Refs. 10 and 11) makes it clear that the violation of special relativity is not in fact one of Hewish's criticisms of our work.

Had it been well founded, the Examiner's objection would have applied to any of the works in Refs. 1–8. Is it conceivable that journals such as *Physical Review E, Journal of the Optical Society of America A, Journal of Applied Physics, IEEE Transactions on Plasma Science, Soviet Physics Uspekhi*, or a Nobel laureate such as V. L. Ginzburg, would publish articles that manifestly violated special relativity?

(b)   The statement "so the speed of the source exceeds the wave speed" is not "in direct violation of known laws of nature, i.e., the Special Theory of Relativity" if the speed is that of the distribution pattern of an electric current and so what constitutes the moving source has no rest mass.

(c)   The word "regime" in "In the highly superluminal regime" is not "unambiguously representing a material object"; the relevant meaning given in the Webster's Dictionary for the word regime is "system". The wording "In the highly superluminal regime" means for those systems in which the speed of the source has a value appreciably exceeding the speed of light. This wording is not "in direct violation of known laws of nature" because the thing whose speed exceeds the speed of light (the source) has no rest mass.

(d)   The word "region" in "this polarized region can be set in accelerated motion with a superluminal velocity" is not "unambiguously representing a material object"; the relevant meanings given in the Webster's Dictionary for the word "region" are "place" and "space". The sentence "this polarized region can be set in accelerated motion with a superluminal velocity" means that the position of the part of space (within the dielectric material) which is polarized can be changed with time in such a way as to create a moving pattern of polarization with an accelerated superluminal velocity. This is not "in direct violation of known laws of nature" because the charged particles (within the dielectric material) whose charge separation gives rise to the creation of the polarized region only oscillate (along a direction that is generally different from the direction of motion of the polarized region) with low (non-relativistic) velocities. The superluminally moving region is created by the coordinated motion of aggregates of subluminally moving charged particles (see Refs. 1–8).

(e)   In the disclosure, we have made it perfectly clear at the outset that our sources are precisely the same as those originally described by Bolotovskii

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and Ginzburg (Ref. 1), i.e., consist of moving distribution patterns which have no rest mass. The phrases "acceleration through the speed of light *in vacuo*" and "centripetal acceleration" are applied in the disclosure to the motion that is associated with the distribution pattern of the electric current. These are defined precisely in the disclosure by giving mathematical expressions for the dependence of the electric charge density on time and on the spatial coordinates [Eqs. (1) and (23) of the disclosure]. The particular examples of superluminal sources considered by Bolotovskii and Ginzburg in Ref. 1 are not accelerated, but the superluminal sources that are discussed by Bolotovskii and Bykov in Ref. 3 *are* accelerated.

There is no mention of the Doppler effect either in the disclosure or in Exhibit D (which is the same as Ref. 8). What the Exminer is referring to is a passing mention of the Doppler effect that is made in Appendix C of Ref. 12, a mention intended merely to help the reader visualize the piling up of wave fronts in the familiar case of emission by moving point sources. The criticisms by A. Hewish (Ref. 10) that are quoted by the Examiner have been replied to in print (see Ref. 11).

It is not the centripetal acceleration of the moving polarized region alone that generates the radiation. The radiation is generated by all those temporal variations that contribute toward a non-zero value of the polarization current density ($\partial \mathbf{P}/\partial t$). The movement of the polarized region *is* physically real with real consequences because it contributes toward the value of the source term $\partial \mathbf{P}/\partial t$ in Maxwell's equations (see Ref. 8). The properties of the radiation that arises from this source term are moreover crucially dependent on the velocity with which the polarized region moves.

(f)   As we have pointed out in our response to Paragraph 4 of the Office Action, the fact that the word "superluminal" appears in the titles of many published papers (e.g. Refs. 1–9) in the very sense used by us means that it is a common terminolgy in the subject and that it can be used in the disclosure without giving rise to any ambiguity or misunderstanding. Likewise, the phrase " accelerated through the light velocity *in vacuo*" is applied in the disclosure to the motion that is associated with the distribution pattern of the electric current. This phrase is defined precisely in the disclosure by giving mathematical expressions for the dependence of the electric charge density on time and on the spatial coordinates [Eqs. (1) and (23) of the disclosure]. By considering electric charges or currents whose distribution patterns move with accelerated superluminal speeds, we have generalized the earlier work of Bolotovskii and Ginzburg (Ref. 1). However, the fact that accelerated superluminal speeds are also considered by Bolotovskii and Bykov in a later paper (Ref. 4) makes it clear that there is no sense in which this generalization

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can be interpreted as an "attempt to stretch out Bolotovskii effect beyond physical reality".

There is no discrepancy between the material presented in the disclosure and those that appear in Atwater's textbook "Introduction to Microwave Theory", or in the patents by Hopwood et al. (USPAT 4,749,995) and O'Donnell et al. (USPAT 4,809,184). Superluminal phase velocities *are* encountered in waveguides, and the non-mechanical beam steering that is achieved by the phase delay between the *discrete* elements of an array of diploe emitters *can* be expressed in terms of the superluminal phase velocity that appears in Eq. (1b) of the Office Action. Neither of these facts, however, have any bearing on the material presented in the disclosure: the properties of the emission that is generated by the invented apparatus are entirely different from those of the emissions that are generated either by (leaky) waveguides or by phased arrays (see Refs. 6–8 and Paragraph 9 below).

The example of the pair of scissors that is given in the affidavit by Dr Rickel directly corresponds to what occurs in our apparatus. The scissors' blades which do not themselves move faster than light correspond to the charged particles in the polarized dielectric material, while the rapidly moving intersection of the scissors' blades corresponds to the superluminally moving distribution pattern of the polarization current. As in the case of the scissors, different parts of the moving distribution pattern of the current are created by the coordinated motion of different charged particles, so that there is no superluminal motion of anything that is material (i.e. has non-zero rest mass).

8.   References 6–8 and 12, which present the theoretical basis and the experimental demonstration of the invention, have already been published in the *Journal of the Optical Society of America A*, in the *Journal of Applied Physics* and in *Physical Review E*. The Examiner's rejection of the invention on grounds of incredibility, inoperativeness and non-enablement is tantamount to questioning the judgement and professional competence of the editors and referees of these highly prestigeous journals.

9.   The fact that the distribution pattern of an electric current density is not material and so can move faster than light without contravening special relativity is a point on which the Examiner agreed with us during the Personal Interview on April 14, 2004. This is something that was witnessed both by the Examiner's supervisor (Dr John R Lee) and by our attorney (Mr John Lastova). And yet the Examiner states that "the term 'distribution' here understood in the art as being of the same nature as its members, i.e., the magnetization current or charge, which is a material object prohibited by

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the law of nature to have a speed exceeding that of light in vacuo". It does not follow from the fact that magnetization current or charge are carried by material objects that their distribution patterns are material. Distribution patterns are like waves; their motion bears no direct relationship with the motion of the continuous medium in which they propagate. But they do carry electric charge and electric current and so can act as sources of the electromagnetic field.

The statement "there is no evidence that applicant's invention is distinguished from a conventional phased array antenna" also represents a retraction of what the Examiner had agreed to in the Personal Interview of April 14, 2004. A conventional phased array antenna consists of a *discrete* set of oscillating dipoles whose adjacent elements are separated from one another by a distance d and differ in phase by a time delay Δt. The beam forming/steering condition for a linear array is simply $c\Delta t = d\cos\theta$, where θ is the angle between the line of elements and the radiation beam. Because its elements are separated from one another, the array generates a field in the radiation zone which is the same as that of a collection of distinct *point-like* sources.

In contrast, the field that is generated by the invented apparatus in the radiation zone is the same as that of an extended, *continuous* source distribution. Since there is no distance between the adjacent electrodes which induce the radiating polarization current (see Fig. 7 of the disclosure and Ref. 8), the distribution of the source that is generated by our apparatus is composed of a collection of adjacent rectangles as shown in Fig. I below. We have shown rigorously (in Appendix A of Ref. 6) that the dominant term in the Fourier decomposition of this source distribution has the form of a continuous travelling wave which propagates along the dielectric ring with a superluminal phase velocity.

For the radiation to have the novel features that are reported in the disclosure, it is essential that the source should be volume-distributed and continuous, rather than discrete (see Refs. 6 and 7). There is a sharp distinction between the superluminal phase velocity $d/\Delta t$ that the Examiner associates with the *discrete* set of elements in a phased array and the superluminal phase velocity of the *continuous* travelling wave that constitutes the distribution pattern of the polarization current in our apparatus. Unless there exists a dense collection of moving source elements (volume elements of the rotating distribution pattern of an extended and continuous electric current density) that approach the observer with the speed of light and zero acceleration along the radiation direction, no cusps could be formed at the position of the observer at the observation time (see Section III of the disclosure in which the notion of the bifurcation surface of an observer is introduced).

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Because the distribution associated with the set of point-like sources in a phased array is not volume distributed, it cannot possibly possess a dense collection of moving source elements that approach the observer with the speed of light and zero acceleration at the retarded time (i.e., it cannot intersect the cusp curve of the bifurcation surface associated with the observation point at more than a few isolated source points). This is why a focusing phased array cannot focus the radiation (as does the invented apparatus) along a space curve which propagates into the far zone ($r \to \infty$).

10.   We have already explained why the invented apparatus is different from "a phased array antenna operating in the beam steering mode". One of the consequences of this difference which has been established both theoretically (Refs. 7 and 12) and experimentally (Ref. 8) is the difference in the decay rates of the intensities of the two emissions with the distance r from their sources. The intensity of the radiation from a conventional source (including a phased array antenna) decays like $1/r^2$, while that of the radiation from the invented apparatus decays like $1/r$. The experimental results plotted in Figs. 11 (a)–(d) of Ref. 8 (the published version of Exhibit D) demonstrate this by showing that the ratio of the intensities of the two types of radiation depends on the distance r linearly (as the ratio of $1/r$ to $1/r^2$ should).

The value of this ratio at a given distance from the transmitter is an independent parameter which is determined by the relative strengths of the sources of the two types of radiation. The effect that is shown in Figs. 11(a)–(d) of Ref. 8 is independent of whether the source of the $1/r$ emission is stronger or weaker than the source of the $1/r^2$ emission. Whatever the relative strengths of the sources of the two types of radiation may be, there is a distance at which the intensity of the $1/r$ emission exceeds that of the $1/r^2$ emission. The fact that the ratio plotted in Figs. 11 (a)–(d) of Ref. 8 has values that are smaller than 1 at $r = 150$ m does not mean that the new emission mechanism is "less efficient" than a conventional one, as claimed by the Examiner; it means that the particular realization of the invented apparatus that is used in the reported experiments generates a weaker polarization current when run superluminally than when it is run subluminally. There is no theoretical constraint on the degree to which the relative strengths of the subluminal and superluminal polarization currents can be controlled by improving the practical implementation of the invented apparatus (see Appendix A of Ref. 6).

11.   Irrespective of their curvature, the conformal phased array (patch) antennae referred to by the Examiner all consist of collections of *discrete* radiating elements, i.e. point-like sources that are separated from one another. We have already explained in Paragraph 9 why the radiation that is emitted

by a *discrete* collection of radiating elements cannot entail a cusp. It is the crucial role played by a cusp that makes the radiation which is emitted by the *continuous* current distribution generated in our apparatus fundamentally different from that which is emitted by a discrete collection of elements. For a cusp to form, i.e., for there to exist a dense collection of moving volume elements of the source that approach the observer with the speed of light and zero *acceleration* along the radiation direction, it is essential that the motion of the distribution pattern of the source should be accelerated as well as superluminal.

12.   We have already explained in Paragraph 9 why the invented apparatus is radically different from a phased array antenna.

13.   The Examiner's reasons for the rejection of claim 61, and hence claims 67–71, disagree with the asessments of the referees and editors of the journals that have published our work. Not only has the theoretical basis of claim 61 been rigorously established by comprehensive analyses that have appeared in prestigeous American journals (Refs. 6, 7 and 12), but the experimental observation of a nonspherically-decaying radiation has also been published by the American Institute of Physics in its *Journal of Applied Physics* (Ref. 8).

14–15.   We have already explained in the preceding Paragraphs why the reasons given by the Examiner for his rejections under §101, 35 U.S.C. 112 and §112/¶.1 are unfounded, and why the invented apparatus is radically different from beam forming/steering or beam scanning/focusing phased array antennae.

16.   There is no contradiction between "the definition, description and derivation of a cusp" and the experimental data. The Examiner is clearly not aware of the distinction between the cusp that is generated by a point source and the cusp that is generated by an extended source such that implemented experimentally (compare Fig. 4 of the disclosure with Fig. II below). [see also Paragraphs 43(a) and 43(e) below].

The cusp that is shown in Fig. 4 of the disclosure is generated by a rotating *point* source, i.e. by a single volume element of the *extended* continuous source that is produced in the apparatus. This cusp both spirals around and moves away from the rotation axis; its projection onto a meridional (r, z) plane has the shape of a parabola (see Fig. 5 of Ref. 7 and Fig. II below). The asymptotes of this prabola approach one another when the element moves with the speed of light, and are further apart from one another, i.e., make a

larger angle with the plane of rotation, the larger is the velocity of the source element.

The cusps that are generated by the extended source in our experimental apparatus, however, are straight rather than spiralling. The dielctric in our apparatus is shaped as a 10° arc of a circle, but the polarization current that is induced in it has the form of a sinusoidal travelling wave which is continually propagating. We can think of our source as one in which the volume elements rotate continually on full circles except that their fields are shielded when their retarded positions fall outside the arc occupied by the dielectric.

Only the cusps generated by those source elements that approach the observer with the speed of light and zero acceleration at the retarded time would pass through the observation point at the observation time. For an observer in the far zone, the azimuthal position φ of such source elements at the retarded time differs from the azimuthal position φ_P of the observer at the observation time by $\pi/2$ [see Eq. (12c) of the disclosure]. This is why the cusp is observable in our experiment only within an azimuthal interval of length 10°. In the case of a rotating point source, the retarded position φ of the source linearly changes with time ($\varphi = \hat{\varphi} + \omega t$) and so the cusp rigidly rotates about the z axis. In the experiment, on the other hand, the position φ of each contributing source element (an element that moves toward the observer with the speed of light and zero acceleration along the radiation direction) is fixed ($\varphi = \varphi_P + 3\pi/2$) and the source elements that occupy that position are constantly changing.

As a result, the cusps generated in the experiment are stationary and straight as shown in Fig. II below. They form an angle with the plane of rotation of the source that is determined by the Čerenkov condition, but they only occupy an interval of width 10° in the azimuthal direction and an interval of width $\sim 2°$ in the polar direction. In order to be able to measure the distance dependence of the intensity of the radiation along the locus of cusps, we tilted the plane of the apparatus by the Čerenkov angle in the experiments to make this locus parallel to the ground (see Ref. 8).

17. The last paragraph in Section I of the disclosure explicitly states that what constitutes a focused wave packet is the segment of the cusp that is generated by a finite-duration source during its lifetime (see also the discussion in Section VII.A of the disclosure). Not only is the theoretical basis of the formation of a cusp (a phenomenon that is also reported by Bolotovskii and Bykov in Ref. 4) presented in Refs. 6, 7 and 12, but the predicted cusp has been observed experimentally (Ref. 8).

The fact that the invented apparatus is radically different from conformal phased arrays is already explained in the preceding Paragraphs 9 and 11.

18–20.   Polarization synchrotron, is defined in the first paragraph of Section VII.B of the disclosure, as "the compact device described in Sec. VI", i.e., as the invented apparatus. We have called this apparatus a polarization synchrotron because it is capable of doing what a conventional synchrotron does (to generate focused pulses of electromagnetic radiation with high frequencies in the near zone). The Examiner's comments on conventional synchrotrons, plasma sleath antennae and waveguides, and on "how to generate and manipulate plasma waves to acquire certain properties" are all unwarranted.

21.   The Examiner alleges that he "disagrees with applicant's persistent claim that all interference effects, thus including beam steering, would vanish beyond the Rayleigh or Fresnel range". Neither in our written response to the first Office Action nor during the Personal Interview conducted on April 14, 2004, have we claimed that "no interference effect could persist for distances longer than the Rayleigh distance". By deriving Examiner's Eq. 2 from first principles on the blackboard, we emphasized in the Interview that no *constructive* interference can occur beyond the Rayleigh distance. The discussion was concerned with the diffraction-free regime of collimated laser beams and not with the steering of a diverging beam from a phased array antenna. The Rayleigh distance is relevant only in the case of emission from apertures or extended sources; it plays no role in beam steering technology where the radiating elements act as disjoint point sources. The Examiner's comments on, and references to, beam steering technology in Paragraph 43(g) of the Office Action are unwarranted.

Whether a collimated laser beam starts spreading at one or at "many multiples" of the Rayleigh distance from its source makes no difference to the fact that the intensity of a laser beam (unlike that of the nonspherically-decaying radiation that is generated by the invented apparatus) decays like $1/r^2$ as $r \to \infty$. The Examiner's long discussion of the work of Melles'Griot on laser beam measurement and his repeated assertion that a "non-spherically decaying component is inherent in light beams resulting from collective interference, such as laser beams and directional beams generated by phased arrays" has no bearing on our claims because a nonspherically-decaying radiation is defined in the disclosure as one whose intensity decays more slowly than $1/r^2$ for $r \to \infty$ rather than for any finite interval in r. The relevant question is whether the alleged nonspherical decay of laser or any other directional beam can (as in the case of the emission from the invented apparatus) persist all the way to infinity, a question the answer to which is clearly no.

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22. The "specific method to control the characteristics of the emitted broadband radiation in order to realize the utility claimed" is to construct the apparatus described in Section VI of the disclosure. The Examiner's contention that our method involves "a broadband radiation generated by a single pulse shock wave" or a "radiation that inherently contains the sum frequency of the carrier frequency and the modulation frequency" (Paragraph 31) are based on his having misunderstood both the disclosure and the Exhibits A and D. A comprehensive theoretical account of the mechanism by which the broadband component of our radiation is generated has already been published in Ref. 6, which was included in Exhibit A. Only the spectrum of the nonspherically-decaying component of our radiation consists of the sum and the difference of the two frequencies used for the synthesis of the source. The spherically-decaying component of the radiation that is generated by our apparatus has a continuous spectrum containing a wide range of frequencies (see Ref. 6).

However, as explicitly stated in Exhibits A and D, and in Ref. 8, the experimental data we have published so far are only concerned with the *amplitude* of the observed emission. Neither is the spectrum of the emission generated by the existing realization of the invented apparatus sufficiently free of contamination by spurious frequencies, nor is the expected efficiency of the radiative process analyzed in Ref. 6 high enough for the data on the predicted broadband emission to be conclusive.

23–24. A message can be encoded into the present type of radiation by any technique that either modulates the amplitude or modifies the shape of the pattern of distribution of the source without altering its superluminal motion, i.e., without altering the speed and the acceleration with which this pattern propagates.

25. The fact that the invented apparatus is radically different from a phased-array anetenna is already explained in Paragraphs 9 and 11 above.

26. The reasons why the Examiner's contention that "the radiation decay characteristics as claimed has been proven to be inherent to many conventional light sources" is erroneous have already been given in Paragraph 21 above.

27. The disclosed claims in which the nature of the source's acceleration is not specified hold true irrespective of whether the acceleration is linear (i.e., in the direction of the dielectric rod) or centripetal (i.e., perpendicular to the dielectric rod). In the present invention, the acceleration is for generating a

cusp (in the envelope of the wave fronts that are emitted by the superlumi-
nally moving volume elements of the distribution pattern of the source) and
not "for beam scanning and/or beam focusing" as assumed by the Examiner.
We have already explained in Paragraphs 9 and 11, above, why the emission
that is generated by various forms of conformal phased array are radically
different from that which is generated by the invented apparatus.

The fact that our radiation is emitted into a direction that lies outside
the plane of rotation does not mean that our "acceleration must be either
(a) something indefinite and unknown in the art, and hence, falls under
present §112/¶.2 rejection, or (b) inadequately described in the disclosure,
and hence, falls under §112/¶.1 rejection, or (c) non-existent, and hence,
inoperative/incredible under §101". It simply means that a new mechanism
of beaming comes into play when the superluminally moving distribution
pattern of the source is accelerated (see Fig. 8 and Section VII.A of the
disclosure).

28. Claim 36 refers to claim 21 in which it is stated that "the apparatus
generates non-spherically decaying electromagnetic radiation", a statement
that specifies the exact meaning of "over long distances without significant
attenuation"; it means an attenuation in accordance to $1/r$ instead of $1/r^2$
for any r (including $r \to \infty$) which appreciably exceeds all other length scales
of the problem. Likewise, claim 68 refers to claim 61 in which it is stated
that the motion of the source "produces non-spherically decaying electromag-
netic radiation". Contrary to the Examiner's interpretation, the attenuation
shown in our experimental data (Ref. 8) is *not* "comparable to that of laser
beams and formed/steered beams from phased arrays". Our experimental
data have tested the $1/r$ prediction up to several hundred Rayleigh distances;
there exist neither comparable claims nor comparable data in the published
literature on "laser beams and formed/steered beams from phased arrays".

We have already dealt with the Examiner's misunderstanding that Figs.
11(a)–(d) of Exhibit D show "signal intensities significantly smaller than r^{-2}
decaying radiation" in Paragraph 10 above.

29. Equations (58)–(60) of the disclosure provide formulae for the precise
location of the region in which the focusing of the waves from a short-lived
source occurs, a location whose coordinates (including its distance from the
transmitter) can be changed at will by adjusting the parameters of the appa-
ratus. As emphasized in Section VII.A of the disclosure, both the underlying
mechanism and the characteristics of this focusing are radically different
from "the focusing capability of laser beams and formed/steered beams from
phased arrays". Our invention makes it possible to emit waves that only

focus at a pre-specified location in space for a pre-specified duration of time, i.e., waves that are dispersed both before and after this focusing.

30. The function of the dielectric substrate in Phelan's invention is to provide "a phase shifting material having a controllable dielectric constant for causing a phase shift of a signal" (US/2003/6,611,230), whereas the function of the dielectric in our invention is to generate a continuous distribution of polarization current over a volume. Phelan's device consists, as any other phased array antenna, of a discrete set of disjoint radiating elements each of which acts like a point-like source from the standpoint of an observer in the radiation zone. For the reasons that we have given in Paragraph 9 in connection with phased-array antennae in general, therefore, Phelan's device is radically different from the apparatus we have described and built. Moreover, we have already explained in Paragraph 21 why it is not true that "a non-spherically decaying electromagnetic radiation is inherent to a focused beam in general", as claimed by the Examiner.

31. We have already explained in Paragraphs 9, 21 and 22, why every one of the analogies that the Examiner draws between Geyeh's device and the apparatus described in the disclosure is false.

32. The Examiner's erroneous contention that the acceleration of the source would lead to "only minor and/or conventional modifications, distortions and/or nonhomogeneities in the radation characteristics" stems from his having overlooked the crucial role that the formation of a cusp plays in our invention. No cusp would form in the absence of acceleration (see Refs. 6, 7 and 12).

We have already explained in Paragraphs 9, 11, 21 and 22, why every one of the analogies that the Examiner draws between Sanford et al.'s antenna array and the apparatus described in the disclosure is false.

33–34. (a) The fact that a non-spherical decay rate is *not* "inherent to a radiation generated by collective interference, such as laser beams and directional beams steered by phased arrays" has already been explained in Paragraph 21 above. (b) There is no "cusp wave front" involved in Hewish's (1996) argument because the motion of the source he considers is not accelerated. The $1/R$ dependence that emerges from Hewish's argument only applies to a (physically unrealsitic) moving source which is infinitely long-lived. (c) The Examiner's statement "It would have been obvious to one of ordinary skill in the art by the time the invention was made to produce a directional beam steered by Phelan's or Geyh's phased array to generate a decay rate $\sim 1/R^x$ with $x < 2$", besides being inoperative, contradicts his

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earlier statement in Paragraph 27 that "While various forms of conformal phased arrays are being operated and investigated all over the world, none of them ever reported to have observed any extra-ordinary effect, including anything like a less-attenuated non-spherical decay behavior". (d) The Examiner's misconception concerning the significance of the Fresnel distance has already been dealt with in Paragraph 21 above. (e) As explained in Paragraph 30 above, the fact that "Phelan's dielectric medium/substrate 16 has a rectilinear shape" is of no relevance to our disclosure. (f) The dielectric antenna structure that is described in our disclosure is as functional for the purposes of implementing our claims as that which appears in Exhibits A and D.

35. For the reasons given in Paragraphs 9 and 11, the works of Wiering and Reffaelli et al. have no bearing on our disclosure.

36. Claim 30 refers back to claim 21 in which it is stated that "the apparatus generates non-spherically decaying electromagnetic radiation". The works of Wick, Geyh and Phelan have no relevance to a non-spherically decaying radiation.

37. As made clear by the reference to claim 61, the mechanism of generating the high-frequency radiation described in claim 66 is radically different from that which is described by Apa et al.; it is crucial to this mechanism that the source is volume-distributed and has a motion that is centripetally accelerated (see Ref. 6). Neither of these two features are present in the work of Apa et al.

38–39. No comment required.

40. The misconceptions that the Examiner has re-iterated here have already been dealt with in Paragraph 21 above.

41. The misconceptions that the Examiner has re-iterated here have already been dealt with in Paragraphs 4 and 7 above.

The fact that the polarization current $\partial \mathbf{P}/\partial t$, and hence the displacement current $\partial \mathbf{D}/\partial t$, arise from the dipole moment that is induced within a unit volume of the dielectric has nothing to do with whether the distribution patterns of $\mathbf{P}$ and $\mathbf{D}$ move subluminally or superluminally. The Examiner's contention that "if there is any acceleration in the experiment, it is the acceleration of an oscillating dipole" stems from his having overlooked the distinction between the motion of charged particles that give rise to the polarization current $\partial \mathbf{P}/\partial t$ and the motion of the distribution pattern of $\mathbf{P}$. It

is the acceleration associated with the motion of the distribution pattern of **P** that is responsible for the formation of cusps and so the novel properties of the disclosed radiation.

The Examiner's erroneous statement that "the experimental geometry coincides with the geometry of a linear phased array, but not with the disclosure (Fig. 4)" has already been dealt with in Paragraph 16 above [see also Paragraph 43(e.3) below].

42.   No comment required.

43(a).   Subsequent publications by Ginzburg (Refs. 2 and 3) and by Bolotovskii and Bykov (Ref. 4) make it clear that the Examiner has missed the essential point of the original paper by Bolotovskii and Ginzburg (Ref. 1). His statement that "it is incorrect to stretch out Bolotovskii's 'superluminal' phase velocity into 'accelerated through the speed of light in vacuo'" has been responded to in Paragraph 7(e) above. The fact that the invented apparatus is radically different from a phased-array anetenna is already explained in Paragraphs 9 and 11 above.

43(a.1).   Nowhere have we said that "the 46 MHz modulation is necessary to generate the claimed radiation characteristics". As far as the amplitude of the radiation is concerned, the only role of this modulation is to separate out the polar angles θ_P at which the spherically-decaying and the nonspherically-decaying components of the radiation peak [compare Eq. (5) in Ref. 8 with the value of θ_P that appears in Section IV of Ref. 8]. For the mechanism of generating high frequencies that is described in Ref. 6, on the other hand, the presence of a modulation frequency Ω (which is not an integral multiple of the rotation frequency ω) is essential.

43(a.2).   The claims in which the curvature of the dielectric medium is left unspecified hold true irrespective of whether the dielectric is curved or linear.

The errors in the Examiner's statements in this Paragraph stem from his confusing the radial component of the polarization current itself with the radial component of the propagation speed of the distribution pattern of the polarization current. If we ignore its modulation, the electric current density that is generated in the reported experiments has the form $\mathbf{j} = j_r \hat{\mathbf{e}}_r + j_z \hat{\mathbf{e}}_z$, where both its radial (j_r) and vertical (j_z) components are functions of ($r, \varphi - \omega t, z$). Thus, the distribution patterns of j_r and j_z both rotate rigidly with the angular frequency ω.

Whether the "dielectic strip has a 4-cm wide open part on its top" or not only determines whether there is a non-zero j_r or not; the emissions from j_r and j_z do not differ from one another in any significant way other than in their polarizations. It is the centripetal acceleration associated with the

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motion of the distribution pattern of the current (i.e., the dependence of $\mathbf{j}$ on $\varphi - \omega t$) that is responsible for the formation of cusps and so the novel properties of the disclosed radiation.

The Examiner does not seem to know that acceleration is a kinematic concept having to do with motion, rather than a dynamical one having to do with inertial mass; he states that "there is no inertial mass involved which could be referred to a real velocity or real motion along a curved path that would eventually cause a real centripetal acceleration".

43(a.3). The distinction between the cusp that is generated by a point source (Fig. 4 of the disclosure) and the collection of cusps that is generated in the experiment (Fig. II below) has already been pointed out in Paragraph 16 above.

43(a.4). It is not true that "the locus of cusp stays confined within, or at least close to, a cylinder formed by the $\pm z$ extension of the circular orbit of the source denoted by circle S in Fig. 1" of the disclosure. (a) In Fig. 1 of the disclosure, S designates the point source itself rather than its circular orbit. (b) Not only have we given explicit expressions for the locus of the cusp, but we have also emphasized that the cusp both spirals around and moves *away* from the rotation axis, eventually reaching $r \rightarrow \infty$. The distinction between the cusp that is generated by a point source (Fig. 4 of the disclosure) and the collection of cusps that is generated in the experiment (Fig. II below) has already been pointed out in Paragraph 16 above.

Nor is it true that "all measurements are made along an x-axis that is perpendicular to the z-axis of Fig. 4 of the disclosure". As shown in Fig. 3 of Ref. 8, the axes along which the measurements are made have the inclinations ϑ_V and ϑ_H relative to the plane of rotation of the source, i.e. make the angles $\pi/2 - \vartheta_V$ and $\pi/2 - \vartheta_H$ with the z-axis of Fig. 4 of the disclosure. The measurements are made along the narrow beam shown in Fig. II below, along a direction which is *not* "perpendicular to the z-axis of Fig. 4 of the disclosure".

The cusp that is shown in Fig. 4 of the disclosure, and reproduced by the Examiner in Fig. 3 of the Office Action, lies at the intersection of two sheets of the envelope of wave fronts shown in Fig. 3 of the disclosure. The "Cerenkov-like cone of radiation" is in this case the two-sheeted surface shown in Fig. 3 of the disclosure and *not* the two cones that the Examiner has drawn on Fig. 3 of the Office Action by hand. The disclosure contains an explicit mathematical demonstration of the fact that the conventional Čerenkov cone is replaced by this two-sheeted cusped envelope when the source point moves with centripetal acceleration.

The radiation patterns shown in Figs. 5A and 5B of the Office Action are manifestly different from those shown in the disclosure and in Fig. II below, simply because the emission from a phased-array antenna does not entail any cusps [see Paragraphs 9 above and 43(c) below].

43(b).   We have explicitly stated in Exhibits A and D, and in Ref. 8, that the experimental data we have published so far are only concerned with the *amplitudes* of the $1/r$ and $1/r^2$ emissions at the two frequencies 552.653 ± 46.042 MHz.   Neither is the spectrum of the emission generated by the existing realization of the invented apparatus sufficiently free of contamination by spurious frequencies, nor is the expected efficiency of the radiative process analyzed in Ref. 6 high enough for the data on the predicted broadband emission to be conclusive.   As far as the amplitude of the radiation is concerned, the only role of the 46.042 MHz modulation is to separate out the polar angles θ_P at which the $1/r^2$ and the $1/r$ components of the radiation peak [compare Eq. (5) in Ref. 8 with the value of θ_P that appears in Section IV of Ref. 8].   For the mechanism of generating high frequencies that is described in Ref. 6, on the other hand, the combined presence of a modulation frequency Ω (which is not an integral multiple of the rotation frequency ω) and centripetal acceleration is essential.

It is not true that "the experiment has failed to support applicant's claimed invention for showing something quite different than what is claimed by the invention".   The experimental data published in Ref. 8 have conclusively established the existence of a sharply focused beam (of polar width $\sim 2°$) along which the radiation decays non-spherically.   While overlooking the fact that both our theoretical and experimental accounts of the invention have been recommended for publication by those experts in the field (the referees of highly prestigeous specialist journals) who have studied them, the Examiner refers to the unsupported opinions reported in the news item <http://physicsweb.org/article/news/8/7/161> as "a general criticism launched by the scientific community, which provides a basis for the §101 rejections raised in this Office Action".

43(c).   It is not true that "the applicant has only considered the radiation under 'subluminal' condition depicted in Fig. 1A as 'conventional'".   A conventional phased array antenna consists of a *discrete* set of oscillating dipoles whose adjacent elements are separated from one another by a distance d and differ in phase by a time delay Δt.   What the Examiner refers to as the superluminal condition for beam forming/steering in the case of a linear array is simply $c\Delta t = d\cos\theta$, where θ is the angle between the line of elements and the radiation beam.   Because its elements are separated from one another,

the array generates a field in the radiation zone which is the same as that of a collection of distinct point-like sources, irrespective of the value of $d/\Delta t$.

In contrast, the field that is generated by the invented apparatus in the radiation zone is the same as that of an extended, *continuous* source distribution. Since there is no distance between the adjacent electrodes which induce the radiating polarization current (see Ref. 8), the distribution of the source that is generated by our apparatus is composed of a collection of adjacent rectangles as shown in Fig. I below. We have shown rigorously (in Appendix A of Ref. 6) that the dominant term in the Fourier decomposition of this source distribution has the form of a continuous travelling wave which propagates along the dielectric ring with a superluminal phase velocity.

For the radiation to have the novel features that are reported in the disclosure, it is essential that the source should be volume-distributed and continuous, rather than discrete (see Refs. 6 and 7). There is a sharp distinction between the superluminal phase velocity $d/\Delta t$ that the Examiner associates with the *discrete* set of elements in a phased array and the superluminal phase velocity of the *continuous* travelling wave that constitutes the distribution pattern of the polarization current in our apparatus. Unless there exists a dense collection of moving source elements (volume elements of the rotating distribution pattern of an extended and continuous electric current density) that approach the observer with the speed of light and zero acceleration along the radiation direction, no cusps could be formed at the position of the observer at the observation time (see Section III of the disclosure in which the notion of the bifurcation surface of an observer is introduced). Because the distribution associated with the set of point-like sources in a phased array is not volume distributed, it cannot possibly possess a dense collection of moving source elements that approach the observer with the speed of light and zero acceleration at the retarded time (i.e., it cannot intersect the cusp curve of the bifurcation surface associated with the observation point at more than a few isolated source points).

The distinguishing feature of our invention is that it replaces the Čerenkov cone by a surface that is cusped (Fig. 3 of the disclosure). Even if the time delays Δt between the adjacent elements of a linear phased array were made progressively shorter so that the speed $d/\Delta t$ depended on the positions of the adjacent elements along the array, the Čerenkov cones shown in Figs. 1–5 of the Office Action would not develop a cusp. The formation of the cusped version of the Čerenkov cone, which is shown in Fig. 8 of the disclosure, requires a source motion that is not only accelerated but also continuous.

43(d). The Examiner's statement, in connection with Fig. 1B of the Office Action, that "each of this wavefront P is a topological equivalent of applicant's envelope shown in Fig. 1 and Fig. 3 of the disclosure" is erroneous.

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Mathematically, there exists no way whatsoever of mapping a cusped surface onto a surface that has no cusp. This reflects the fact that a rectilinear motion with constant velocity is generically different from a circular motion, which is accelerated.

The Examiner's statement "the higher harmonics denoted by a number 'm' is/are not produced by the 'rotation of polarization current', as claimed in Exhbit D/Eq. 36 & Eq. 2 (Table 1), Exhibit B/Eq. 7 and Exhibit C/Eq. 9a, but a mere result of applicant's auxiliary modulation by 46 MHz" contains several misconceptions. (a) The frequency $m\omega = 552.654$ MHz in which the number m appears is an input parameter; it is the frequency of the sinusoidally varying voltage that we apply to the electrodes to *induce* the polarization current. (b) The 46 MHz is another input parameter; it is the frequency associated with the voltage that is applied to the electrodes without any phase shift. (c) The equations referred to by the Examiner all describe the polarization current that we induce in the dielectric rather than describing anything that is supposed to be produced by the resulting polarization current.

The Examiner's statements about the spectrum of the radiation have already been replied to in Paragraph 43(b) above.

43(e).   The Examiner's assertion that "all the radiation characteristics claimed as being the exclusive results of applicant's invention can be adequately explained by conventional beam forming & beam steering/focusing theory without postulating or speculating the existence of any 'cusp'" is unfounded. Our apparatus (whose length is of the order of only a wavelength of the radiation it emits) has been observed to generate a focused beam of width $\sim 2°$ with an intensity that decays like $1/r$, rather than $1/r^2$, over the experimentally available range (which amounts to several hundred Rayleigh ranges). No radiation with such characteristics has ever been reported in the published literature.

43(e.1).   The Examiner has completely missed the point, made after Eq. (12c) of the disclosure, about the coalescence of three waves at the cusp. Any observer who is located within the envelope of wave fronts receives three waves simultaneously, the three waves shown in Fig. III below. These waves are emitted at three diferent retarded times when the source was positioned at the points I_1, I_2 and I_3 in the figure. In the case of an observer who is located on the cusp, these three waves and the three retarded positions I_1, I_2 and I_3 from which they originate coalesce. It is this coalescence of three waves that makes the field on the cusp stronger than the field on the envelope itself. An observer who is located on the envelope only receives two waves simultaneously. In Ref. 4, Bolotovskii and Bykov have given a

detailed account of this feature of emission by superluminal sources for the case of Čerenkov effect, where any observer who is located within the envelope receives *two* instead of *three* wave fronts simultaneously. The Examiner's contention that "in general there can be a large number of wavefronts that intersect each other to form a cusp" is particlarly revealing; it shows that he has not understood even the most basic feature of the mechanism (the constructive interference of coalescing waves) described in the disclosure.

43(e.2). The Examiner's comments in this Paragraph contain a number of misconceptions. (a) The circle which the Examiner interprets as "the linear array S in applicant's Fig. 1" is just the trajectory of a point source, the point source designated as S.

(b) The cusp that is shown in Fig. 4 of the disclosure is generated by a rotating *point* source, i.e. by a single volume element of the *extended* continuous source that is produced in the apparatus. This cusp both spirals around and moves *away* from the rotation axis; its projection onto a meridional (r, z) plane has the shape of a parabola (see Fig. II below and Fig. 5 of Ref. 7). The asymptotes of this parabola approach one another and coincide when the element moves with the speed of light, and are further apart from one another, i.e., make a larger angle with the plane of rotation, the larger is the velocity of the source element.

(c) The Lagrangian coordinate $\hat{\varphi} \equiv \varphi - \omega t$ (called Lagrangian as opposed to Eulerian, in the sense used in continuum mechanics) has the value zero in Fig. 1 of the disclosure; it labels the rotating source element that is at $\varphi = 0$ at the time $t = 0$. When the source is continuous and extended, we label each of its volume elements with the value of $\hat{\varphi}$ which that element has at time $t = 0$. Each volume element generates a cusp as shown in Fig. 4 of the disclosure, so that a localized source with a limited extent in $\hat{\varphi}$, generates a bundle of spiralling cusps.

The $\hat{\varphi}$ extent of the source in our experimental apparatus is 2π, i.e., the entire range of values of $\hat{\varphi}$ (see Ref. 6). The cusps that are generated in this case are straight, as in Fig. II below, rather than spiralling for the following reason. The dielctric in our apparatus is shaped as a 10° arc of a circle, but the polarization current that is induced in it has the form of a sinusoidal travelling wave which is continually propagating. We can think of our source as one in which the volume elements rotate continually on full circles except that their fields are shielded when their retarded positions fall outside the arc occupied by the dielectric.

Only the cusps generated by those source elements that approach the observer with the speed of light and zero acceleration at the retarded time would pass through the observation point at the observation time. For an observer in the far zone, the azimuthal position φ of such source elements

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at the retarded time differs from the azimuthal position φ_P of the observer at the observation time by $\pi/2$ [see Eq. (12c) of the disclosure]. This is why the cusp is observable in our experiment only within an azimuthal interval of length $10°$. In the case of a rotating *point* source, the retarded position φ of the source linearly changes with time ($\varphi = \hat{\varphi} + \omega t$) and so the cusp rigidly rotates about the z axis. In the experiment, on the other hand, the position φ of each contributing source element (an element that moves toward the observer with the speed of light and zero acceleration along the radiation direction) is fixed ($\varphi = \varphi_P + 3\pi/2$) and the source elements that occupy that position are constantly changing.

As a result, the cusps generated in the experiment are stationary and straight as shown in Fig. II below. They form an angle with the plane of rotation of the source that is determined by the Čerenkov condition, but they only occupy an interval of width $10°$ in the azimuthal direction and an interval of width $\sim 2°$ in the polar direction. In order to be able to measure the distance dependence of the intensity of the radiation along the locus of cusps, the plane of the apparatus was tilted in the experiments to make this locus parallel to the ground (see Ref. 8).

(d) The entire analysis in Ref. 7 is devoted to calculating the properties of the bundles of cusps which are generated by an *extended* source. It follows from that analysis and from the points (a)–(c) made above that the Examiner's contention that the locus of the cusp is "smeared out $2n\pi$-fold around the z axis" in the case of the "traveling wave implemented in the experiment" is erroneous. The locus of cusps in the reported experiments is as that shown in Fig. II below.

(e) It is true that the far field intensity decays like $1/A$ where A is the cross sectional area of the beam, but it is not true that A increases like r^2 as claimed by the Examiner. The beam that is generated by our invention is non-diffracting in one dimension: in the direction parallel to the rotation axis. Its polar beamwidth $\Delta\theta_P$ decreases like $1/r$ with increasing r, so that its cross sectional area A only increases as r. If we denote the extent of the source in the z direction by Δz, then the bundle of cusp curves that reaches an observer at the polar angle θ_P has the polar width $\Delta\theta_P = \Delta z \sin\theta_P/r$ (see Fig. II below). This follows from Eq. (12b) of the disclosure, from pinpointing those volume elements of the extended source that move towards the observer with the speed of light and zero acceleration along the radiation direction, and from specifying the cusp curves that are generated by each of them.

43(e.3).   The Examiner's comments in this Paragraph contain a number of misconceptions. (a) There is no inconsistency between the cusp locus as described in the disclosure and as described in the experiments. The cusp that is generated by a point source (the one shown in Fig. 4 of the disclosure)

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comes closest to the z axis on the plane of the source's orbit where it touches and is tangential to the light cylinder $r = c/\omega$ (or $\hat{r} = 1$). It then spirals around and moves away from the z axis; its projection onto a meridional (r, z) plane has the shape of a parabola (see Fig. II below and Fig. 5 of Ref. 7). Both in Fig. 4 of the disclosure, where the orbit of the source is given by $r = 3c/\omega$, and in the experiments reported in Ref. 8, where the orbit of the source is given by $r = 1.06c/\omega$, the cusp starts within the source's orbit at $z = 0$, $\hat{r} = 1$, and quickly moves to radii that lie outside this orbit as it spirals away both from the axis and from the plane of rotation. The same holds true for the cusps shown in Fig. II below that are generated by the invented apparatus for $r = 3c/\omega$ (see the preceding Paragraph for the distinction between the spiraling cusp that is generated by a point source and the straight cusps that are generated by the experimental apparatus).

(b) The measurements are *not* "taken at different cusp locations as a function of distance measured in reference to the x-axis that lies on the plane of the array and is tangent to it", as alleged by the Examiner. The direction along which the measurements are taken makes the angle $\vartheta_H = 20°$ with the plane of the array. The plane of the array was tilted relative to the gorund so that distances could be measured along the locus of the cusps, parallel to the ground (see Ref. 8).

The Čerenkov cones that the Examiner has drawn in Figs. 3 and 5B of the Office Action bear no relationship with the directions in which the intensities of either the $1/r$ or the $1/r^2$ component of the radiation we have observed peak.

(c)   Figure II below, in conjunction with Paragraphs 16 and 43(e.2) above, should clarify the Examiner's misinterpretation of the geometry of the experiment and the polar diagram of the observed radiation.

43(e.4).   The fact that the conical apex of the envelope of wave fronts shown in Fig. 1 of the disclosure is coincident with the point source S, and so the envelope of wave fronts that issues from it rigidly rotates together with S, has already been emphasized in the disclosure. The envelopes that the Examiner has drawn on Fig. 2 of the Office Action in broken lines simply represent snapshots at earlier times of the moving envelope that is shown in solid lines. So, the Examiner's statement that "These envelopes constitute a series of new, second order wavefronts for the propagation vector **k** of the emitted radiation from a curved array" (in which the meaning of "second order wavefronts" remains unclear) must stem from a misunderstanding. Moreover, an envelope of wave fronts invariably represents a site of constructive interference and so focusing. It is difficult to see what the Examiner means when he says that "these curved envelopes or second order wavefronts represent either a converging (focused) or diverging (defocused) beam".

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43(f).   (a) We have already explained in Paragraph 9 above why there is a sharp distinction between the superluminal phase velocity $d/\Delta t$ that the Examiner associates with the *discrete* set of elements in a phased array and the superluminal phase velocity of the *continuous* travelling wave that constitutes the distribution pattern of the polarization current in our apparatus. The Examiner is mistaken in thinking that there is no difference between a superluminal phase velocity and a phase shift. Superluminally moving continuous sources of the electromagnetic field have been created in the laboratory also by shininig a moving pulse of X-rays onto a medium that can be ionized (Ref. 5), i.e., by methods involving no phase shift.

(b) The Examiner's confusion concerning Eq. 1c of the Office Action stems from the fact that the θ coordinate of a cusp coincides with the apex angle θ of a Čerenkov cone in the far zone.

The source point approaches any observation point P that is located on the envelope of wave fronts (the two-sheeted Čerenkov-like surface shown in Fig. 3 of the disclosure) with the speed of light along the radiation direction; this means that the far-field value of the θ_P coordinate of the observation point P is given by Eq. 1c of the Office Action. On the other hand, the source point approaches an observation point that is located on the *cusp curve* of the envelope of wave fronts not only with the speed of light but also with zero acceleration along the radiation direction; this fixes not only the far-field value of the θ coordinate of the observation point in question, but also the far-field value of its azimuthal coordinate φ_P. The radiation that arises from each element of our source is beamed into a given direction (specified by the values of both θ_P and φ_P at infinity), rather than being "distributed over the surface of a Cerenkov-like cone", as alleged by the Examiner in Paragraph 43(i).

(c) An electric current with a moving distribution pattern acts as a source of electromagnetic radiation irrespective of whether the speed of its distribution pattern is smaller or greater than the speed of light. An example is synchrotron radiation which is generated by (subluminally moving) electrons in circular motion. The following argument by the Examiner is therefore false: "The fact that applicant could still measure a signal although the imaginative phase velocity is only $V_d = 0.875c$ is a solid evidence that applicant's radiation is completely conventional".

43(g).   The Examiner alleges that he "disagrees with applicant's persistent claim that all interference effects, thus including beam steering, would vanish beyond the Rayleigh or Fresnel range". Neither in our written response to the first Office Action nor during the Personal Interview conducted on April 14, 2004, have we claimed that "no interference effect could persist for distances longer than the Rayleigh distance". By deriving Examiner's Eq. 2

from first principles on the blackboard, we emphasized in the Interview that no *constructive* interference can occur beyond the Rayleigh distance. The discussion was concerned with the diffraction-free regime of collimated laser beams and not with the steering of a diverging beam from a phased array antenna. The Rayleigh distance is relevant only in the case of emission from apertures or extended sources; it plays no role in beam steering technology where the radiating elements act as disjoint point sources. The Examiner's comments on, and references to, beam steering technology are unwarranted.

The waves that are emitted by the entire volume of a *subluminally* moving source do "contribute by way of interference to the intensity" beyond the Ryaleigh range, as stated by the Examiner. In the case of a superluminally moving source, on the other hand, only the waves arising from that part of the source contribute which lie within the bifurcation surface of the observation point (see Section III of the disclosure). In either of these cases, the contributions would not be by way of *constructive* interference, however, if the observation point lies at a distance from the source that appreciably exceeds the Fresnel distance.

The misconceptions that the Examiner has expressed in "since applicant's cusp is smeared out around the z-axis, and/or the radiation is distributed over a Cerenkov-like cone" have already been commented on in Paragraph 43(e.2) above.

Moreover, from the fact that phase shifs or time delays can be implemented in many different ways, it does not follow that "'superluminality' is only a product of fantansy or imagination", or that "'accelerated through the light velocity in vacuo' should never be used in technical and scientific articles", as argued by the Examiner [see our explanations in Paragraphs 7(e), 9 and 43(f) above].

43(h).   (a) No reasons are given either by the Examiner or by those whom he quotes why "a range of 10–80 km is more likely needed to test the $\sim 1/R^2$ intensity decay, instead of a mere 900 m range measured in applicant's experiment". There is no parameter other than the Fresnel distance to limit the range of validity of the results that are reported in Refs. 8, and these results have been tested upto several hundred Fresnel distances. The range needed for testing a prediction of Maxwell's equations is not something that is determined by people's opinions; it is dictated by Maxwell's equations themselves. The validity of the solutions of Maxwell's equations that we have presented in the disclosure and in Refs. 7 and 12 are not subject to any restrictions whatsoever beyond the Fresnel distance.

(b) The radiation from the linear phased array considered by Hewish (which is continuous) would have a $\sim 1/R$ intensity dependence for all R only if the array is infinitely long. When the array's length Δz is finite,

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the $1/R$ dependence breaks down beyond $R = (\Delta z \sin\theta)^2/\lambda$, as can be seen from Hewish's equation that the Examiner has quoted [Eq. (3) of the Office Action]. This distance, beyond which the $1/R$ cannot hold, is the Fresnel distance as expected. Given that there can be no cusp in the case analyzed by Hewish (the speed of his source is uniform), it is not of course unexpected that the $1/R$ dependence should break down beyond the Fresnel distance.

The Examiner's contention that "Being linear and one-dimentional, applicant's array is in fact an inherent part of the conventional two-dimensional array (Fig. 5A)" stems from his having overlooked the significance of the cusp which the curvature of our array gives rise to. As we have already pointed out in Paragraph 43(a.4) above, the radiation patterns shown in Figs. 5A and 5B of the Office Action are manifestly different from those shown in the disclosure and in Fig. II below simply because the emission from a phased array antenna does not entail any cusps [see also Paragraphs 9 and 43(c) above].

43(i).   (a) None of the US Patents referred to by the Examiner in this Paragraph have any relevance to our invention. We have already explained in Paragraphs 9 and 11 above why our invention is radically different from any phased array antenna, whether of the dipole or patch variety.

(b) The Examiner is mistaken in thinking that "Compared to the conventional 2-dimensional array of Fig. 5A, which emits a steered beam in a definite direction represented by the vector **k**, the beam of applicant's linear array is distributed over the surface of a Cerenkov-like cone with apex angle θ determined by Eq. 1c". The $1/r$ component of the radiation by our apparatus is distributed over the bundle of *cusps* of the Čerenkov-like cones that are generated by various volume elements of the source (see Paragraph 16 above and Fig. II below). The Examiner's confusion stems from the fact that the θ coordinate of a cusp coincides with the apex angle θ of a Čerenkov cone in the far zone.

The source point approaches any observation point P that is located on the envelope of wave fronts (the two sheeted Čerenkov-like surface shown in Fig. 3 of the disclosure) with the speed of light along the radiation direction; this means that the far-field value of the θ_P coordinate of the observation point P is given by Eq. 1c of the Office Action. On the other hand, the source point approaches an observation point that is located on the *cusp curve* of the envelope of wave fronts not only with the speed of light but also with zero acceleration along the radiation direction; this fixes not only the far-field value of the θ coordinate of the observation point in question, but also the far-field value of its azimuthal coordinate φ_P. The radiation that arises from each element of our source is beamed into a given direction (specified by the

values of both θ_P and φ_P at infinity), rather than being "distributed over the surface of a Cerenkov-like cone", as alleged by the Examiner.

(c) The expression derived by the Examiner for the shift of the f_+ and f_- propagation direction in Eq. (5) of the Office Action also follows from Eq. (5) of Ref. 8 in the far-field limit (where $R/R_P \to 1$ in that equation) and so is correct. But this agreement between our results and those which hold in the Čerenkov case stems, once again, from the fact that the θ coordinate of a cusp coincides with the apex angle θ of a Čerenkov cone in the far zone; it does not "provide altogether a solid evidence that applicant's invention is nothing else than conventional beam steering" because the emission from the invented apparatus propagates into a pencil beam formed by a bundle of cusps rather than over the surface of a Čerenkov cone [see (b) in this Paragraph]. The Examiner's misconception that "the experimental geometry agrees with the Cerenkov-like radiation cone of a linear phased array, i.e., expressible in (x, θ_x, φ_x) coordinates with x being on the plane of the array" has already been dealt with in Paragraph 43(e.3)(b) and (c) above.

43(j).   (a) The intensity of the radiation from a conventional source (including a phased array antenna) decays like $1/r^2$, while that of the radiation from the invented apparatus decays like $1/r$. The experimental results plotted in Figs. 11 (a)–(d) of Ref. 8 (the published version of Exhibit D) demonstrate this by showing that the ratio of the intensities of the two types of radiation depends on the distance r linearly (as the ratio of $1/r$ to $1/r^2$ should).

The value of this ratio at a given distance from the transmitter is an independent parameter which is determined by the relative strengths of the sources of the two types of radiation. The effect that is shown in Figs. 11(a)–(d) of Ref. 8 is independent of whether the source of the $1/r$ emission is stronger or weaker than the source of the $1/r^2$ emission. Whatever the relative strengths of the sources of the two types of radiation may be, there is a distance at which the intensity of the $1/r$ emission exceeds that of the $1/r^2$ emission. The fact that the ratio plotted in Figs. 11 (a)–(d) of Ref. 8 has values that are smaller than 1 at $r = 150$ m does not mean that the new emission mechanism is "less efficient" than a conventional one, as claimed by the Examiner; it means that the particular realization of the invented apparatus that is used in the reported experiments generates a weaker polarization current when run superluminally than when it is run subluminally. There is no theoretical constraint on the degree to which the relative strengths of the subluminal and superluminal polarization currents can be controlled by improving the practical implementation of the invented apparatus (see Appendix A of Ref. 6).

The Examiner has totally misinterpreted Figs. 11(a)–(d) of Ref. 8; these figures are not intended "to justify that $P_{\mathrm{cusp}}/P_{\mathrm{sub}}$ tends to exceed unity for

R values larger than 800m". The value of R at which this ratio exceeds unity is not what matters. Figures 11(a)–(d) are intended to demonstrate the fact that $P_{\text{cusp}}/P_{\text{sub}}$, is a linearly increasing function of R over the interval in which the measurements are made. We have not reported *any* result in Ref. 8 whose validity depends on "only one single data point in Fig. 11(a) among many hundreds of others, moreover lying well within the statistical scatter of the data", as alleged by the Examiner.

Equally unfounded is the Examiner's allegation that our nonspherically decaying emission "inevitably violates the energy conservation law". The calculation presented by the Examiner is based on the assumption that the cross-sectional area of the nonspherically decaying beam increases like r^2 with the distance r from the source. However, the beam that is generated by our invention is non-diffracting in one dimension: in the direction parallel to the rotation axis. Its polar beamwidth $\Delta\theta_P$ decreases like $1/r$ with increasing r, so that its cross sectional area A only increases as r. If we denote the extent of the source in the z direction by Δz, then the bundle of cusp curves that reaches an observer at the polar angle θ_P has the polar width $\Delta\theta_P = \Delta z \sin\theta_P/r$ (see Fig. II below). This follows from Eq. (12b) of the disclosure, from pinpointing those volume elements of the extended source that move towards the observer with the speed of light and zero acceleration along the radiation direction, and from specifying the cusp curves that are generated by each of them.

The remaining allegations made by the Examiner in this Paragraph have already been responded to in Paragraphs 21 and 43(h)(a) above.

(b) We have already responded in the preceding Paragraphs to every one of the points that the Examiner reiterates here.

We should add that the directive gain of our antenna, by virtue of increasing with the distance r from the source, would considerably exceed those of the conventional antennae referred to by the Examiner (which are independent of r) in the far zone. The fact that the measured values of $P_{\text{cusp}}/P_{\text{sub}}$ are smaller than unity in Ehibit D does not mean that our antenna has a low directive or power gain. It means that the particular realization of the invented apparatus that is used in the reported experiments generates a weaker polarization current when run superluminally than when it is run subluminally (see Paragraph 10 above). There is no theoretical constraint on the degree to which the relative strengths of the subluminal and superluminal polarization currents can be controlled by improving the practical implementation of the invented apparatus (see Appendix A of Ref. 6).

43(k). We have already explained in the preceding Paragraphs why none of the statements referred to by the Examiner in (a)–(d) are incredible. Moreover, none of the travelling wave antennae mentioned in (e) entail a travelling wave with an *accelerated* superluminal motion.

43(l). We have already explained in the preceding Paragraphs why the distribution pattern of the source that is generated by our apparatus is, unlike those of the sources generated in phased arrays, continuous and propagates with an accelerated superluminal motion.

The Examiner is mistaken in thinking that "the conventional technique of beam steering and beam focusing with phased arrays has been misconstrued by applicant by imagining it as a 'motion' that is 'accelerated to superluminal speed'. whereas in reality there is no motion whatsoever". The distribution patterns of the sources that are used in the scanning and focusing phased arrays referred to by the Examiner (which focus the radiation at a single stationary point like a lens) do not entail any motion, but those of the sources that are generated in our apparatus (which are extended and continuous) do.

43(m). We have already explained in the preceding Paragraphs why we do not agree with any of the Examiner's statements here. Quite apart from our detailed response in the preceding Paragraphs, just the fact that comprehensive accounts of both the theoretical and experimental aspects of our invention have been published by prestigeous American journals suffices to discredit the Examiner's conclusion that the "applicant's claimed invention is inconsistent with the known scientific principles".

43(n). (a) On the one hand, the Examiner contends that the "applicant's claimed invention is inconsistent with the known scientific principles" and on the other hand he states that "there is no evidence whatsoever that the measured non-spherical decay is exclusively due to the applicant's unique apparatus design and method, as claimed". Not only is there no inconsistency between the invention and known scientific principles, but our contributions in pointing out the possibility of generating a non-spherically decaying radiation in the laboratory, and designing, constructing and testing of the apparatus for generating such a radiation are all without precedence.

(b) The experimental data we have presented already establish the fact that the invented apparatus is capable of delivering signal powers and directive gains that are substantially higher than those of any conventional transmitters of electromagnetic radiation [see Paragraphs 43(h)(a) and 43(j)(b) above].

(c) Figure II below, in conjunction with Paragraphs 16 and 43(e.2) above, should clarify the Examiner's misinterpretation of the geometry of the experiment and the polar diagram of the observed radiation.

(d) We have explicitly stated in Exhibits A and D, and in Ref. 8, that the experimental data we have published so far are only concerned with the *amplitudes* of the $1/r$ and $1/r^2$ emissions at the two frequencies 552.653 ± 46.042 MHz. Neither is the spectrum of the emission generated by the existing realization of the invented apparatus sufficiently free of contamination by spurious frequencies, nor is the expected efficiency of the radiative process analyzed in Ref. 6 (Exhibit C) high enough for the data on the predicted broadband emission to be conclusive.

44. (a) Examiner's response to points (1) & (2), and (3) & (4) of Dr Rickel's affidavit require no comment.

(b) None of those statements in the disclosure that the Examiner refers to in his response to points (5) & (6) of Dr Rickel's affidavit violate the special theory of relativity. As we have explained in Paragraphs 4 and 7 above, what acts as the source of electromagnetic radiation in our apparatus is not the type of object that is barred from moving faster than light by special relativity. The example of the pair of scissors that is given by Dr Rickel directly corresponds to what occurs in our apparatus. The scissors' blades which do not themselves move faster than light correspond to the charged particles in the polarized dielectric material, while the rapidly moving intersection of the scissors' blades corresponds to the superluminally moving distribution pattern of the polarization current. As in the case of the scissors, different parts of the moving distribution pattern of the current are created by the coordinated motion of different charged particles, so that there is no superluminal motion of anything that is material (i.e. has non-zero rest mass).

A *source* of electromagnetic radiation need not be material or have rest mass. Superluminally moving distribution patterns of macroscopic charges and currents act as sources of the electromagnetic field in precisely the same way as any other moving sources of these fields (see Refs. 1–5 below). Nor is the motion that is associated with the distribution pattern of a macroscopic charge or current restricted in any way; it can be with or without acceleration. Terms such as "superluminal velocity" and "superluminal source" are common terminology in the literature on the subject which have appeared in the titles of numerous published papers.

As we have explained in Paragraphs 9–11 above, there is a sharp distinction between the superluminal phase velocity that the Examiner associates with the *discrete* set of elements in a phased array and the superluminal phase velocity of the *continuous* travelling wave that constitutes the distribution pattern of the polarization current in our apparatus (see Fig. I below).

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Unless there exists a dense collection of moving source elements (volume elements of the rotating distribution pattern of an extended and continuous electric current) that approach the observer with the speed of light and zero acceleration along the radiation direction, no cusps would be formed at the position of the observer at the observation time. It is the crucial role played by a cusp that makes the radiation which is emitted by the *continuous* current distribution generated in our apparatus fundamentally different from that which is emitted by a discrete collection of elements.

(c) It is not true that the "Affiant is arguing along the same line with the examiner", as stated in the Examiner's response to point (7) of Dr Rickel's affidavit. What acts as a source of electromagnetic radiation need not have a non-zero rest mass (i.e., need not be material); it only needs to have a non-zero electric charge or carry a non-zereo electric current. The intersection of the scissors' blades that moves with a superluminal speed in Dr Rickel's example *would* cause Čerenkov radiation if it is charged (see Refs. 1–5 below). Likewise, the moving distribution pattern of a macroscopic charge or current deos act as a source of electromagnetic radiation—irrespective of being non-material and having no rest mass.

(d) What the Examiner states in his response to point (8) of Dr Rickel's affidavit stems from a number of misunderstandings, misunderstandings which we have already dealt with in Paragraphs 16, 17, 21, 43(a.3–4), 43(e.2) and 43(j) above.

There are no discrepancies between our derivation of the cusp in the disclosure and our experimental data. The spiralling cusp that is shown in Fig. 4 of the disclosure is generated by a rotating *point* source. The cusps that are generated experimentally, i.e. by an extended continuous source distribution, are stationary and straight as shown in Fig. II below. The direction along which our measurements are made is not perpendicular to the axis of rotation, as alleged by the Examiner; the apparatus was tilted so that this direction falls outside the plane of rotation along the cusp. The experimental data we have presented already establish the fact that the invented apparatus is capable of delivering signal powers and directive gains that are substantially higher than those of any conventional transmitters of electromagnetic radiation [see Paragraphs 43(h)(a) and 43(j)(b) above].

The energy conservation law is not violated because the beam that is generated by our invention is non-diffracting in one dimension: in the direction parallel to the rotation axis. Its polar beamwidth decreases like $1/r$ with increasing r, so that its cross-sectional area increases as r rather than as r^2 (see Fig. II below). Thus, the flux of energy across any given surface enclosing the source is independent of r (as required by the conservation of energy).

The nonspherical decay of a laser or any other directional beam cannot persist all the way to infinity. Whether a collimated laser beam starts spreading at one or at "many multiples" of the Rayleigh distance from its source makes no difference to the fact that the intensity of a laser beam (unlike that of the nonspherically-decaying radiation that is generated by our apparatus) decays like $1/r^2$ as $r \to \infty$. The diffraction-free regime of no conventional collimated beam can persist far beyond the Rayleigh distance. In contrast, the prediction that the $1/r$ decay rate of our radiation should hold as far as $r \to \infty$ has been tested to several hundred Rayleigh distances. There exist neither comparable claims nor comparable data in the published literature on laser or any other beams. Moreover, Dr Rickel's explanation of the observed nonspherical decay in terms of focussing is fully consistent with the mathematical derivation of this effect that is presented in the disclosure.

(e) The Examiner's response to point (9) of Dr Rickel's affidavit is also based on misconceptions. We have already discussed the difference between conventional phased arrays and our apparatus in Paragraphs 9–11 above, and the difference between collimated laser beams and our nonspherically-decaying radiation in Paragraph 21 above.

Consisting of a *discrete* set of radiating elements, a conventional phased-array antenna generates a field in the radiation zone which is the same as that of a collection of distinct *point-like* sources. In contrast, the field that is generated by the invented apparatus in the radiation zone is the same as that of an extended, *continuous* source distribution (see Fig. I below). For the radiation to have the novel features that are reported in the disclosure, it is essential that the source should be volume-distributed and continuous, rather than discrete.

A nonspherically-decaying radiation is defined in the disclosure as one whose intensity decays more slowly than $1/r^2$ for $r \to \infty$ rather than for any finite interval in r. The nonspherical decay of a laser or any other directional beam cannot persist all the way to infinity. Whether a collimated laser beam starts spreading at one or at "many multiples" of the Rayleigh distance from its source makes no difference to the fact that the intensity of a laser beam (unlike that of the nonspherically-decaying radiation that is generated by our apparatus) decays like $1/r^2$ as $r \to \infty$.

(f) The statements made by the Examiner in his response to point (10) of Dr Rickel's affidavit have already been shown to be erroneous in Paragraphs 9, 43(b), 43(c) and 43(f) above.

An electric current with a moving distribution pattern acts as a source of electromagnetic radiation irrespective of whether the speed of its distribution pattern is smaller or greater than the speed of light. An example is synchrotron radiation which is generated by (subluminally moving) electrons

in circular motion. The following argument is therefore false: "As described above in the examiner's evaluation section, the experiment does not simulate a true Čerenkov effect, because the array keeps radiating even if the phase velocity is subluminal".

The following statement is also false: "Even if the dipole distribution is homogeneous, such that no 'phase velocity' can be attributed to the dipole distribution (without modulation), the array will keep radiating." In the absence of temporal modulation, the flux of energy associated with the field of such an array would not be non-zero at infinity.

It is not true that "Essential is only the role of the time delay $\Delta t = 140$ ps in making the imagined phase velocity superluminal". Unless the superluminal motion of the distribution pattern of the source is accelerated (i.e., the array is curved), the envelope of wave fronts that are emitted by its individual volume elements would not be cusped. The role of the 46 MHz modulation in the reported experiments is to separate out the polar angles θ_P at which the $1/r^2$ and the $1/r$ components of the radiation peak [compare Eq. (5) in Ref. 8 with the value of θ_P that appears in Section IV of Ref. 8]. For the mechanism of generating high frequencies that is described in the disclosure and in Ref. 6, on the other hand, the combined presence of a modulation frequency Ω (which is not an integral multiple of the rotation frequency ω) and centripetal acceleration is essential.

We have already explained in Paragraph 9 above why there is a sharp distinction between the superluminal phase velocity $d/\Delta t$ that the Examiner associates with the *discrete* set of radiating elements in a phased array and the superluminal phase velocity of the *continuous* travelling wave that constitutes the distribution pattern of the polarization current in our apparatus. The Examiner is mistaken in thinking that there is no difference between a superluminal phase velocity and a phase shift. Superluminally moving continuous sources of the electromagnetic field have been created in the laboratory also by shininig a moving pulse of X-rays onto a medium that can be ionized (Ref. 5), i.e., by methods involving no phase shift.

The two distinguishing features of our invention are (1) that it entails a continuous rather than a discrete source distribution, and (2) that it replaces the Čerenkov cone by a surface that is cusped (Fig. 3 of the disclosure). The similarity between Eqs. 1a–d of the Office Action and the limiting forms of some of our equations stems (1) from the correspondence between the beam-forming/steering and the Čerenkov conditions, and (2) from the fact that the θ coordinate of a cusp coincides with the apex angle θ of a Čerenkov cone in the far zone.

The Examiner's assertion that "the result of the measurement is nothing else than the conventional result of exciting a conventional array by a

DSB/SC modulation technique" is unfounded. Our apparatus (whose length is of the order of only a wavelength of the radiation it emits) has been observed to generate a focused beam of polar width $\sim 2°$ with an intensity that decays like $1/r$, rather than $1/r^2$, over the experimentally available range (which amounts to several hundred Rayleigh ranges). No radiation with such characteristics has ever been reported in the published literature.

As we have already explained in Paragraph 43(j) above, the Examiner's statements concerning "inconsistencies between the experimental geometry and the disclosure" stem from a lack of undestanding of the contents both of Exhibit D and of the disclosure. The fact that the ratio plotted in Figs. 11(a)–(d) of Ref. 8 (the published version of Exhibit D) has a value that is smaller than 1 at $r = 150$ m does not mean that the new emission mechanism is less efficient than a conventional one, as alleged by the Examiner; it means that the particular realization of the invented apparatus that is used in the reported experiments generates a weaker polarization current when run superluminally than when it is run subluminally. We have not reported *any* result in Ref. 8 (Exhibit D) whose validity is "based on one single data point that is an exemption among others", as alleged by the Examiner.

(g) The Examiner has totally misinterpreted Figs. 11(a)–(d) of Ref. 8 (Exhibit D) in his response to point (11) of Dr Rickel's affidavit. Figures 11(a)–(d) are intended to demonstrate the fact that the ratio $P_{\text{cusp}}/P_{\text{sub}}$ of the powers emitted by the superluminal and subluminal sources is a linearly increasing function of R over the interval in which the measurements are made. The value of this ratio at a given distance from the transmitter is an independent parameter which is determined by the relative strengths of the two types of sources. The effect that is shown in Figs. 11(a)–(d) of Ref. 8 is independent of whether the source of the $1/r$ emission is stronger or weaker than the source of the $1/r^2$ emission. Whatever the relative strengths of the sources of the two types of radiation may be, there is a distance at which the intensity of the $1/r$ emission exceeds that of the $1/r^2$ emission. The fact that the ratio plotted in Figs. 11 (a)–(d) of Ref. 8 has values that are smaller than 1 at $r = 150$ m does not mean that the $1/r$ decay rate is "irrelevant", as alleged by the Examiner; it means that the particular realization of the invented apparatus that is used in the reported experiments generates a weaker polarization current when run superluminally than when it is run subluminally. There is no theoretical constraint on the degree to which the relative strengths of the subluminal and superluminal polarization currents can be controlled by improving the practical implementation of the invented apparatus (see Appendix A of Ref. 6).

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Figure captions

Figure I. The pattern of distribution of the polarization **P** as a function of the azimuthal angle φ along the dielectric ring. Snapshots of this distribution are shown at four consecutive times. The rectangle functions designate the (sinusoidally time-varying) polarizations that are induced by the (sinusoidally time-varying) voltages across various electrodes. The distribution represented by the collection of the adjacent rectangle functions can be expanded, at any given time, into a Fourier series with respct to φ. The smooth curve in each snapshot designates the dominant term in this Fourier series. It has been shown rigorously in Appendix A of Ref. 6 that the difference between the step-wise distribution pattern of **P** and the sinusoidal travelling wave that constitutes the dominant term of its Fourier representation is negligibly small in our experiments, where there are over 20 electrodes within each wavelength of the generated travelling wave. Thus the distribution pattern of our source is, in contast to that of a phased array antenna, smooth and *continuous*.

Figure II. Spatial and angular extent of the nonspherically-decaying emission generated by the invented apparatus. The cylinder designates $r = c/\omega$ (i.e., the light cylinder), the dotted circle designates $r = 3c/\omega$, $z = 0$ (i.e. the orbit of a source point with the same velocity as that shown in Fig. 1 of the disclosure), and the $10°$ arc on the plane $z = 0$ designates the position of the dielectric rod in the invented apparatus. The thickness of the dielectric rod in the z direction is highly exaggerated here in order that the non-diffracting dimension of the emitted beam shows up clearly. The separation in z of the upper and lower boundaries of the beam (the two fan-shaped surfaces shown in the figure) remains the same as the z-extent of the source at all distances r. The radiated beam subtends a constant angle $\Delta\varphi$ in the longitudinal direction which equals the azimuthal extent ($10°$) of the source. The width $\Delta\theta$ of the beam in the polar direction, on the other hand, decreases like $1/r$ with r. Thus the flux of energy, i.e. the product of the cross sectional area of the beam and the intensity of the $1/r$ component of the radiation remains constant with r. In the reported experiments the source speed is $1.063c$ (rather than $3c$ as here and in Fig. 1 of the disclosure) and so the angle $\arcsin[c/(r\omega)]$ between the beam and the z-axis is wider than that in this figure.

Figure III. The three wave fronts (designated by full circles) which simultaneously pass through an observation point P located inside the envelope (the two-sheeted surface designated by the heavier curves). The larger of the two broken circles is the orbit of the source point S and the smaller

designates the light cylinder $r = c/\omega$. (This figure depicts, as in Fig. 1 of the disclosure, the cross sections of the wave fronts and their envelope with the plane of the source's orbit.) Even though they are received simultaneously, the three wave fronts that are shown here were emitted at three distinct instants of emission time when the source ocuppied the retarded positions I_1, I_2 and I_3. Two of the wave fronts coalesce, and so interfere constructively, when the observation point P approaches the envelope. All three of the wave fronts coalesce when P approaches the cusp of the envelope. It is the coalescence and constructive interference of waves on the envelope and its cusp that give rise to the progressively higher intensities of the radiation on these loci.